EMERGENT AGENTS AND THE SIMULATION OF POLITICAL UNREST: APPLICATION TO PALESTINIAN POLITICAL COALITIONS

L.A. KUZNAR,* J. TOOLE, and N. KOBELJA,
Indiana University–Purdue University, Fort Wayne, IN

ABSTRACT

Computational social science uses agent-based computer models for simulating social phenomena from the "bottom up," allowing social phenomena to emerge from the interactions of individual agents. This approach grounds social phenomena in entities that have a clearer and more concrete existence. Yet higher order social phenomena, such as alliances, kin groups, villages, and states, at times act on goals that transcend those of their constituent members. Programming special rules for higher-order phenomena fails to capture their emergent nature. We model the emergence of radical political coalitions in Palestinian society and explore the possibility of their evolving group-level actions.

We have developed a theoretical tool, expo-sigmoid utility theory, to model the risk-sensitive behavior of agents. Expo-sigmoid utility theory is derived from the empirical observation that wealth is typically distributed from poorest to wealthiest, with quasi-periodic fluctuations around an overall exponential increase. Such distributions are typical in chiefdoms, ancient states, modern states, and the global economy. Individuals whose social rank places them on a convex (concave upward) section of a wealth curve behave in risk-prone ways; they take chances for social advancement that most individuals would avoid. Our empirical research shows that the risk proneness of individuals in a coalition is a necessary, although not necessarily sufficient, condition for collectively violent behavior.

In this paper, we utilize data on wealth distribution in the Palestinian Authority to model the formation and evolution of political coalitions within Palestinian society. We consider two primary influences on coalition-joining behavior: risk sensitivity and communication proximity. Agents play a coordination game with their neighbors, and their probabilities of taking a risk (in this case joining a coalition) are altered by their risk sensitivities. Coalitions form as emergent phenomena, exhibit collective measures of risk sensitivity, and change by the same rules as individuals, producing new attributes for these emergent agents. Risk-prone coalitions socially isolate their individual agents, in accordance with social psychology theories, altering the situational definition that agents use for decision making. Preliminary validation of the model is done by a comparison with historical developments in Palestinian political alliances.

Keywords: Agent-based modeling, emergence, adaptive agents, terrorism, Palestine

* *Corresponding author address:* Lawrence A. Kuznar, Decision Sciences and Theory Institute and Department of Anthropology, Indiana University–Purdue University, Fort Wayne, IN 46805; kuznar@ipfw.edu.

INTRODUCTION

Dynamically adaptive agents, emergent phenomena, and the agent-like behavior that is exhibited by emergent phenomena characterize social processes (Barabasi 2003; Watts 2003). Realistic modeling of social phenomena therefore requires researchers to enable simulations to produce adaptive agents and emergent phenomena, and it requires emergent structures to behave dynamically in a manner that is greater than the sum of their parts (Holland 1998; Axelrod and Cohen 2000).

Nowhere is this need more apparent than in the simulation of radical political behavior and terrorist activity. Terrorist organizations seemingly materialize out of nothing and adapt dynamically to changing political circumstances and military confrontation (Stern 2003; Arquilla et al. 1999). In this paper, we describe a simulation of political activism and terrorist activity in which we strive to incorporate realistic individual- and group-level dynamics. We apply our results to a consideration of political activity and terrorist recruitment within contemporary Palestinian society.

TERRORISM AS AN ADAPTIVE SYSTEM

Analysts argue that terrorism has entered a new era characterized by a decidedly international scope, a horizontal organization, and an ability to change and adapt to rapidly changing circumstances (Ellis 2004; Hoffman 1999). Terrorist organizations are now made up of increasingly diverse individual agents who coalesce into relatively independent cells that change with shifting social conditions. For instance, al Qaeda began with a relatively top-down command-and-control organization and recruited Jihadis from Islamic countries such as Egypt, Saudi Arabia, Yemen, and Pakistan. Increasingly, al Qaeda recruits in Western nations, it lacks explicit command and control from its founders, and its members appear to act independently on the basis of a general notion of waging a Jihad against the West. Terrorist organizations and their attendant political manifestations exhibit the classic features of an adaptive system of agents who coalesce into emergent social forms that behave by their own rules.

SIGMOID UTILITY THEORY, POLITICAL ACTIVISM, AND TERRORISM

Sigmoid utility theory provides an explanation and a method of prediction for risk-taking behavior. The basic concept is that individuals would accept gambles with negative expected value if the potential gains of such gambles exceeded the potential losses (Friedman and Savage 1948). Kuznar (2001, 2002) operationalized this concept and demonstrated its relevance in a variety of cultural settings. Kuznar and Frederick (2003) developed the concept further and demonstrated its applicability to political activist and rebellious behavior. They found that ranking individuals in a society on a wealth scale (x-axis) from poorest to wealthiest and then measuring each individual's wealth on the y-axis produces an oscillating, S-shaped or sigmoidal curve of wealth differences (Figure 1). This S-shaped oscillation occurs along a generally exponential increase in wealth in complex societies (chiefdoms, states, global economies), leading the authors to call such distributions expo-sigmoid (Kuznar and Frederick 2005). Convex (concave upward) wealth distribution curves imply that potential gains from a gamble typically exceed losses, leading to risk-prone behavior (acceptance of negative expected utility). Because

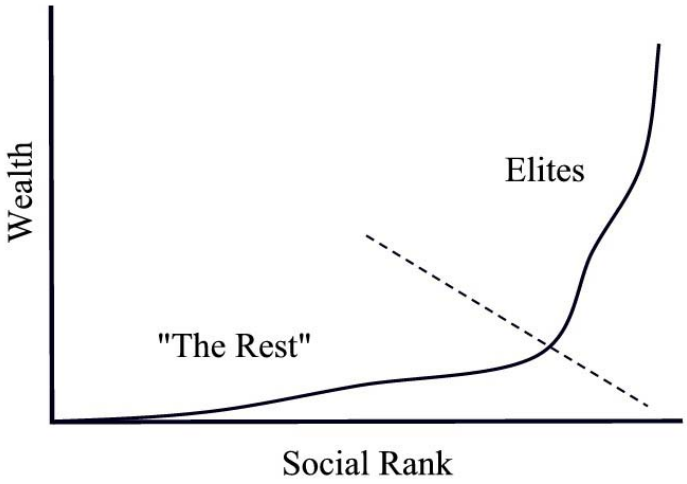

FIGURE 1 Expo-sigmoid wealth distribution

political activism and terrorism are risky, sigmoid utility theory is applicable to these phenomena. Our preliminary research indicates that other dimensions along which humans are valued (social status in terrorist groups, regard in religious organizations) also distribute expo-sigmoidally, and so the method is applicable beyond strict material economic applications. However, our research also shows that concerns over material wealth often lurk behind many revolutionary activities. The advantage of the sigmoid utility approach over other economic theories is that it gets us beyond simplistic poverty-based explanations of rebellion and terrorism.

The close study of the demographics of any revolution demonstrates that few poor people ever rebel and that comparatively wealthy individuals typically lead rebellions (Brinton 1964). Recent studies of terrorist recruitment demonstrate that there is a near-zero correlation between wealth and terrorist activity (Krueger and Maleckova 2002, 2003; Palmer Harik 1996). Even comparatively wealthy individuals can find themselves in a convex distribution of wealth or status and correspondingly feel much aggrieved that they are not as well off or as well regarded as their near superiors. As aggrieved individuals seek one another out, rebellious coalitions can emerge spontaneously from across a social spectrum, often under the banner of nationalism, ethnic identity, or religious affiliation (Kuznar et al. 2005).

We use the Arrow-Pratt measure of risk aversion (Pratt 1964), $r(x)$, to measure an individual's sensitivity to risk by fitting an expo-sigmoid curve, $W(x)$, to a wealth distribution over some wealth or status, x. Negative values of the measure indicate risk proneness, positive values indicate risk aversion, and zero values indicate risk neutrality.

SOCIAL PSYCHOLOGY OF TERRORIST AND EXTREMIST GROUPS

Studies of the social psychology of terrorist groups demonstrate that group members actively work to isolate recruits from their families and the wider society (Stahelski 2004; Hudson 1999; Post 1990). Such isolation reinforces group goals and an individual's attachment to and dependence on a terrorist group (Soibelman 2004). It also reinforces the group's

situational definition, the classification of others, and the emotional attachment of an individual to a group or a cause (Sallach and Mellarkod 2005; Jackson, 2002).

There exists a continuum — from groups that are so socially isolated that they remain small, suffer from shared distortions of reality, and lack networked contacts that can fuel funds and expertise, to groups that are so open that they are easily infiltrated by new ideas and personnel and consequently never achieve a stable identity or goal (Axelrod and Cohen 2000, pp. 50-52). In this project, members of risk-prone groups avoid joining with nonmembers in proportion to the overall risk proneness of their current group. Agents in risk-neutral to risk-averse coalitions join or defect with others according to the rules applied to individual risk sensitivity.

This approach imbues a risk-prone coalition with the social dynamic described in social psychological studies of terrorist groups: as individuals join radical groups, their individual perceptions of reality are brought more in line with the group's view, while the groups both psychologically and physically isolate members from the outside world. Such groups begin to take on a life of their own, and their members behave in a coordinated fashion so that the emergent group itself will begin to behave as though it was an individual agent, in accordance with rules that originally applied to individuals. Our approach also recognizes that while resentment over economic inequalities may be an initial factor in an individual's decision to join a radical group, these psychological factors may increase in importance with a group's evolution.

SIMULATING COALITION FORMATION IN PALESTINE

Axelrod (1997) advocates the use of simple, abstract simulations for exploring the basic relationships between parameters. On the other hand, if simulations are going to capture the complexity and dynamism of real social systems, then researchers need to develop more complicated and realistic models (Kuznar 2005). However, the complexity of realistic simulations makes establishing the causal relationships between variables nearly as difficult as in simulations as it is in the real world. Our intention in this exercise is to provide a simulation in which the relationships between parameters are apparent but in which there is enough verisimilitude to make a reasonable connection to real social phenomena.

The first step in establishing a model's realism is to use real data as inputs. We use data on the average incomes of Palestinians provided by the Palestinian Authority (Palestinian National Authority–Palestinian Central Bureau of Statistics 2003) to initialize the wealth distribution in the model. The Palestinian data have the classic expo-sigmoid distribution of a complex society. To fit a curve to these data, we first take the natural log of the data, and then we produce a periodogram to establish the dominant frequencies that create the oscillations in the curve (Lomb 1976). Once the dominant frequencies are identified, we produce a trigonometric polynomial, plus a linear term and a constant, by multiplying sine and cosine terms by the coefficients of the dominant frequencies from the periodogram. That equation is then used as the argument for an exponential function, yielding an equation of the general form:

$$W(x) = e^{f(x)},$$

where $f(x) = k + ax + \Sigma\ c_i\ sin(x) + d_i cos(x)$ for i dominant frequencies. Our simulation uses 256 agents assigned wealth according to the initialized function and ranked according to their wealth.

We model agent coalition formation and its payoffs with a variety of game variously referred to as the stag hunt or coordination game (Battalio et al. 2001). This game has two equilibria — either both players defect or both players cooperate — and the Nash optimum is to play a mixed strategy of join and defect (Table 1).

This game is especially useful for modeling the payoffs associated with joining a rebellious coalition. Many people never join rebellions, simply continuing on with their lives and earning the payoffs they normally expect from life. However, if rebels were to succeed, rebel payoffs would be much higher. Refusing to join a rebellion usually has no particularly severe punishments, although there can be exceptions. The risk-averse choice in this game is to defect (not join or cooperate) and continue to earn moderate payoffs. The risk-prone choice is to join (or cooperate with the high payoff) because of the risk that one's partner will defect. We randomly assign agents for game play within their Moore neighborhood, mimicking small-scale, face-to-face societies.

Once each player has played the game, the agents are ranked according to their wealth levels. We then fit a curve to these data and use divided difference numerical techniques to estimate the first and second derivatives for each agent over the wealth function. These estimates are then used to produce the Arrow-Pratt risk sensitivity measure for each agent. The Arrow-Pratt measures alter the probability of joining. We alter the probabilities in proportion to the degree to which an agent is either risk prone or risk averse. The most risk-prone agent always joins, and join probabilities are altered continuously up to the most risk-averse agent, who never joins. Coalitions form when agents join. If an activated agent solicits another agent and it joins, then the activated agent joins the other agent's coalition.

Once coalitions form, average risk sensitivities for these coalitions are calculated. Then the agents' probability of joining with nonmembers is altered in the reverse fashion from individual agent probabilities. The probability of joining with a nonmember is varied

TABLE 1 Payoff matrix for coordination game[a]

	Column Player	
Row Player	Join	Defect
Join	(R, R)	(S, T)
Defect	(T, S)	(P, P)

[a] Payoffs where R > T = P > S reflect the relative benefits and costs of joining and defecting from a rebellious coalition.

continuously, from zero for members of the most risk prone (most insular) coalition, to the Nash optimum for risk-neutral agents.

RESULTS

Relatively stable coalitions emerge by iteration 75, making comparisons to empirical data useful. In iteration 75, there are 22 coalitions and 2 independent agents. The coalitions range in size from 2 to 29 members, with a mean of 12. The risk sensitivity of coalitions is an average of –0.00064 and ranges from –0.017 to 0.026. Since we are interested in political radicalism and terrorism, we concentrate on the most risk-prone coalitions.

Figure 2 shows the distribution of agents from the three most risk-prone coalitions. Two results may be particularly important for understanding the emergence of radical groups, terrorist recruitment, and the long-run behavior of such groups. First, all groups contain agents from a range of wealth levels. Coalition 3 is the most striking because it is simultaneously the most risk-prone group and composed entirely of agents from the upper half of the wealth distribution. Once again, wealth or poverty per se is not important, only the relative wealth differences measured by the convexity of wealth distribution curves. The other two coalitions (20 and 63) contain a mix of impoverished and relatively wealthy agents. Second, coalitions 20 and 63 contain a minority of risk-averse agents. This is possible because each agent plays a mixed strategy, so there is usually a probability that an agent can either join or defect from a coalition. While a Nash mixed strategy does not model the precise mechanism by which otherwise risk-averse individuals would join a radical group, it nonetheless provides for this real-world possibility. Both of these basic results may help explain the curious lack of correlation between wealth and terrorist activity, despite the facts that terrorist groups often cite economic grievances and that terrorists recruit in impoverished neighborhoods.

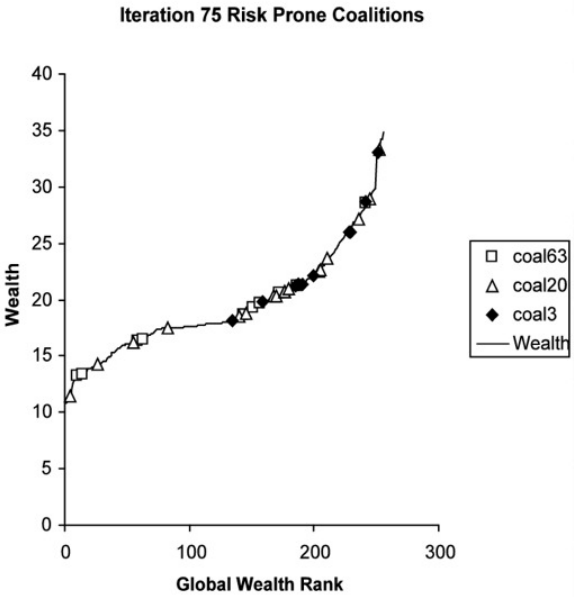

FIGURE 2 Agents of the three most risk-prone coalitions in iteration 75

The risk sensitivity of all coalitions changed dynamically through time with changes in the collective fortunes and risk sensitivities of group members (Figure 3). Coalition 3 was the shortest-lived of the three coalitions and remained risk-prone throughout its history. Coalition 20 was the most dynamic, swinging from risk prone to risk averse, but fluctuations were drastic. Coalition 63 follows a secular trend in the simulation, toward general risk neutrality but, once again, with unpredictable fluctuations between risk proneness and risk aversion. These fluctuations, along with the variable lives of coalitions, mirror the dynamic lives of real Palestinian political parties and radial groups (Rubin 1999).

DEMOGRAPHICS OF PALESTINIAN RADICAL GROUPS

Most studies of Palestinian political and terrorist groups are qualitative, and the few quantitative studies present aggregate statistics that mask the details of wealth and status distribution. Therefore, complete validation of our model is not possible. However, some comparisons can be made, and they indicate the potential of our approach.

The data on socioeconomic status and political involvement/terrorism are mixed for Palestine. Some studies find no correlation (Krueger and Maleckova 2003), some find a positive correlation between wealth and radicalism (Inbar and Yuchtman-Yaar 1989, Table 3), some document that the political elite originate from elites and upwardly mobile middle-class families (Brynen 1995, page 39), some note that suicide bombers tend to come from poor communities (Weinberg et al. 2003, page 143; Pedahzur et al. 2003, page 418), and others argue that economic deprivation is an insufficient explanation of radicalism (Moghadam 2003, page 76; Soibelman 2004, page 185).

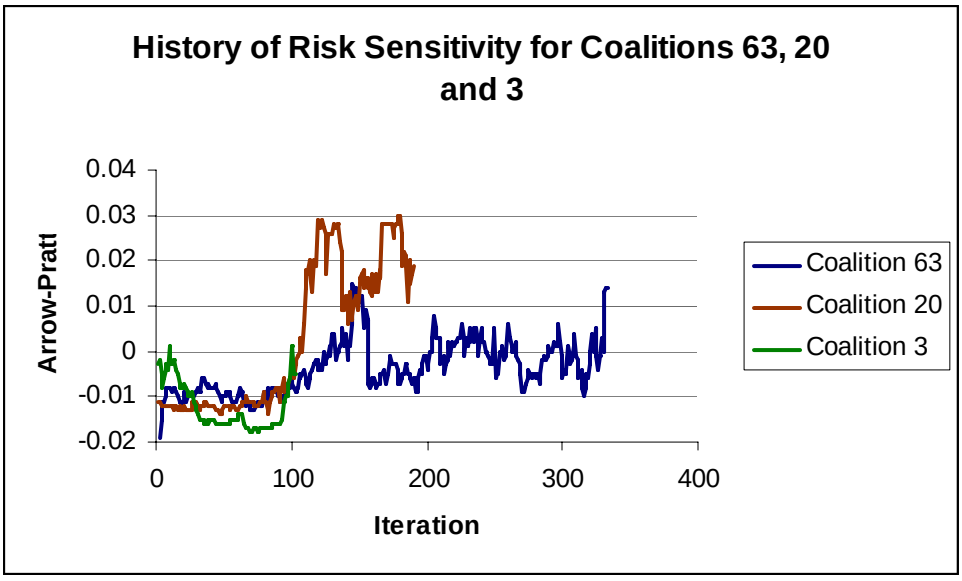

FIGURE 3 History of risk sensitivity for coalitions 63, 20, and 3

The simulation outputs, however, provide an explanation for the mixed results of empirical studies. First, since risk proneness occurs at the low and high ends of the wealth distribution, any correlation between wealth and risk is bound to be near zero. The fact that the most risk-prone coalition in iteration 75 (coalition 3) was statistically significantly wealthier than the whole population ($p = 0.01$) and found among the wealthiest half of the agents mirrors the origin of some radical groups from the middle-class and university community (Paz 2003, p. 35) and the derivation of the political elite from upper- and middle-class families (Brynen 1995). On the other hand, the mean wealth of the other two coalitions in iteration 75 was not statistically significantly different from the population, with one coalition being slightly higher and the other being slightly lower than the mean. These coalition results resemble the data found by other researchers (Krueger and Maleckova 2003). The problem with standard approaches is that they ignore the important variability in wealth distributions that mask relevant variation and lead to mixed results. Our approach utilizes a fresh approach by considering the significance of relative wealth differences and using the flexibility of simulation to produce these varied results.

CONCLUSION

Our simulation of political group formation based on economic risk sensitivity focused on a few key factors that could explain the mixed demographics of radical groups within Palestinian society. Our programming approach allowed agent's preferences to evolve through time. Agent coalitions were not hard-coded but instead emerged according to autonomous agent decisions. We further altered agent behavior to make agents more insular once risk-prone coalitions emerged. The social isolate algorithm we used allowed coalitions to behave dynamically and in accordance with individual behavioral rules as though they themselves were agents. This approach thoroughly grounds the dynamic behavior of emergent phenomena in the interactions among their constituent elements (Holland 1998). The result was a simulation that contains essential elements for realistic modeling of complex phenomena: autonomous agents, emergent phenomena, and emergent behaviors for these phenomena. The model produced results that were consistent with qualitative analyses of Palestinian radical groups.

In order to improve upon our preliminary approach, future work will include: alternative decision rules, more boundedly rational agents, alternate games and alternate payoffs for sensitivity analysis, changed random seeds to produce a range of possible runs, and more detailed empirical data for better validation.

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